On the Italian contribution to radar

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***Abstract*— The Italian contribution to radar is little knows due to scarce and sometimes imprecise literature. This paper aims to cover naval and coastal radar developments in Italy from the beginning (1935) to the halt due to the Armistice of September 8th, 1943, mostly due to Ugo Tiberio and Nello Carrara.**

***Keywords*— Radar, History, Radar Equation, Gufo (Owl), Ship Defence, RIEC, Istituto Vallauri, Ugo Tiberio, Nello Carrara.**

I. Introduction

The history of the radar development through the original patent (Hülsmeyer, 1904) has been presented in tens of books and in hundreds of papers, see for instance the References of [1]-[13], and discussed during the international conferences in 2004, 1985 and other. The continuing interest on this area is shown by the appearance of papers and books even after the *"centenary boom"* in 2004/5, as in [6], [12], [13]. Most of the literature is by English or American authors (to name a very few books amongst the most widely known: [9]-[11]). This is not surprising, as Anglo-Americans are the winners of the W.W. II, in which the radar had an important role (and according to somebody, a fundamental one). Moreover, most books and papers written in 2004 and before by Anglo-American authors neglect the Italian contributions to radar (similarly, but even more than the contributions by France [7], Germany [8], USSR/Ukraine [14], Netherlands [3], Japan [15] and other nations). For example, [10], a volume of nearly six hundred pages, cites the developments of the Italian radar in only 10 (ten) lines, skipping over the E.C. 3/Owl (Gufo) and Italian industrial radars. Even in the French-Author's book [7] the Italian contribution occupies only 2 (two) pages out of 430. The book [6], in Italian, aims to remedy to this situation, and some of its key elements pre-1944 are presented, with the needed updates, in the following. They are related to the *Gufo*, to the radar equation (U. Tiberio). Beforehand, critical mention is made on to the IRE speech and the field "experiments" by G. Marconi.

II. Guglielmo Marconi and the Radar

In [1] it is claimed that critical spirit is a key element (not only to/by radar engineers) to teach and learn. Without it, errors *"propagate"* and replicate themselves endless, especially in the present *"Internet era"*. A good practice may be deflating myths such as the one that the British invented the radar, see [16], a myth that Robert Watson Watt defended along his (happy and long) life. In front of C. Hülsmeyer, Watson Watt continued to attribute to himself the paternity of radar, and only admitted that Hülsmeyer was - as a maximum – *"the grandfather"* of radar. A less understood myth is the one that Marconi announced the radar (1922) and realized it (1935) in Italy. Both claims (although repeated in many documents (e.g. at pages 51, 127/128 of [5], 40 and 162 of [7], 30 and 341 of [12], etc.) are basically false, see pages 7-12 and endnotes 28-51 of [6]. Summing up:

a) It is not true that Guglielmo Marconi first proposed the concept of radio detection in a speech at the American Institute of Electrical Engineers and Radio Engineers on June 20th, 1922. In fact, Marconi's speech, also reported in the paper "Radio Telegraphy", IRE Proc. Vol. 10, 1922, is very generic, purely conceptual and does not add anything to the more precise, but seldom referenced, paper by N. Tesla, published five years before (in August, 1917) on "The Electrical Experimenter" (see also [6], endnote 33, and [7]).

b) Most books, see above, report the Marconi's *"discovery"* of the beat effect in 1933 due to the passage of a metallic object (according to some, a steam roller, to other, a wheelbarrow or a lawnmower) in the short-wave test-installation between Castel Gandolfo and the Vatican. A few books, however, recall that eleven years before, in September 1922, those interference were analyzed by Albert Hoyt, Y. Taylor and Leo C. Young due to the passage of a wooden vessel, the Dorchester, on the Potomac river, south of Washington, which created a sequence of maximum and minimum intensity on a side-shore radio link at the wavelength of 5*m*. In his report dated September 27, 1922, Taylor prefigured the use of the interferences (beats) to detect enemy ships passing through the line joining the transmitter to the receiver. Hyland and Young observed the beats due to the passage of an aircraft since 1930, with a demonstration made by A. H. Taylor in December 1930, and an IRE publication by C. Englund et al. in 1932, see p. 410 of [7] and Figure 1.

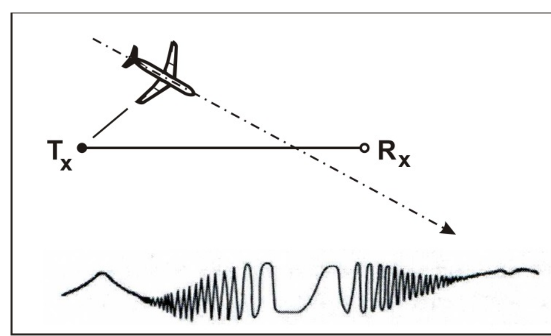


Fig. 1. The beating phenomenon when a target crosses a radio link line of sight.

At pages 15 and 16 of [18] there is the list of experiments (1922-1933) in which the presence of moving objects (but not their exact position) was detected due to their crossing of a radio link. Defense systems based on this principle were deployed in France in the 1930's thanks to Pierre David.

c) The reader interested to the Marconi's experiments (really, only "shows" for the public) with his "Radioecometro" (Acquafredda, near Roma, 14 May 1935, with the presence of Benito Mussolini, see Figure 1.6 of [6]; Roma-Ostia road, 17 May 1935 and Boccea road, 20 May 1935) analysed in pages 9-11 of [6]. Here we only mention that these "Radioecometri" were proposed by Marconi against land vehicles or troops, an impossible task at those times, due to the lack of highly stable frequency generators and of the capacity of suppression of disturbing echoes due to soil, vegetation, etc. (MTI canceller). No development at all resulted from these experiments, unless maybe the rise of interest in radar by General Luigi Sacco (present on 14 May 1935) who involved the Regia Marina (Italian Navy) and Ugo Tiberio (who did never met Marconi) in the development of the Italian radar, treated in next Section. At the international level, the presence of the British secretar of Marconi, Gaston Mathieu at the Acquafredda experiments did not change at all the situation in the United Kingdom. In fact, the secret memorandum by Robert Watson Watt on radar was submitted to the Rector of the Imperial College of Science and Technology on February 4th, 1935 and the first experiments in Daventry, with the detection of a bomber from the RAF using the signals transmitted by the BBC, occurred in February 1935, about three months prior to the Marconi's experiments.

d) About all the alleged experiments by Marconi on radar it has been impossible to find any technical note, written report, or similar, in spite of extensive research made on 2014 in the State Archives (Archivio Centrale di Stato, Italy), [17].

This Section ends with a not obvious, original (excluding the Italian book [6]) and "negative" result: the contribution to the radar development by Guglielmo Marconi was zero or very close to zero. Vice versa, the company he founded (the English Marconi) gave a significant industrial contribution to the development of the first British radar-based system, i.e. the Chain Home.

III. THE VALUABLE ITALIAN CONTRIBUTION TO RADAR

The "positive" side of the radar developments in Italy is due to the work of a few, highly valuable researchers and engineers. As explained in [1]-[13], and in many other documents, military radar was developed independently, under strict secrecy, by many nations in the 1930's under the pressure of the international crisis before W.W. II. The "instigator" of the Italian radar was the general Luigi Sacco (1883-1970), see Figure 2, the author of the celebrated "Manual of Cryptography" who, at the time, was chief of the Transmissions area in the *Direzione Superiore Studi ed Esperienze* (DSSE) of the Military Engineering. The strategy by Luigi Sacco was to assign the developments of new means for radio communication and radio location to the most technically ready among the Armed Forces, i.e. the Navy. So, Ugo Tiberio (1904-1980), see Figure 2, since 1931 engineer at the *Instituto Militare Superiore delle Transmissioni* in Rome, requested to be transferred to the RIEC (*Regio Istituto Elettronica e Telecomunicazioni* i.e. Royal Electronics and Communications Institute, the current *Istituto Vallauri*, or *CSSN ITE* - Italian Navy) in Livorno, which was effective in 1936. Tiberio was appointed Naval Weapons officer and transferred at the Naval Academy as a professor of physics and radio techniques.



Fig. 2. Luigi Sacco (1883-1970), (left) and Ugo Tiberio (1904-1980).

The group led by Ugo Tiberio at the RIEC in Livorno, was entrusted with the task of going from the theoretical studies[1] to the experimental phase of the radar development. However, the financial resources and the available staff were limited (four petty officers, some workers and an annual budget of 20,000 lire - about thirteen thousand Euro). In practice Tiberio had to start almost alone the development and the implementation of the prototype of the *Radiotelemetro* (the Italian name for radar, which of course was secret; often written in coded form: RaRo, pl. RaRi ; another name was *Radio Detector Telemetro* , RDT). Soon, Tiberio was flanked by a physicist, Nello Carrara (1900-1993), another professor of physics at the Naval Academy. Through 1924 Nello Carrara [19], see Figure 3, was working at the RIEC and, since 1932, did researches in the microwave field.



Fig. 3. Nello Carrara (1900-1993). From [19], courtesy of Franco Samoggia.

[1] The Tiberio's "Found Manuscript" dated 27/4/1936 - XIV, a theoretical basis of radar, is deeply discussed in Chapt.2 of [6].

He was mainly responsible for the design and implementation of high power tubes, fundamental components needed to obtain acceptable values for the radar range. In 1937 the captain of Naval Weapons ing. Alfeo Brandimarte (1906-1944) joined the group of RIEC radar researchers, and immediately began to work for the new prototype of the E.C.3, pulse radar to be described later. This collaboration, however, was short lived because the possibility of career progression in the Italian Navy was precluded to Brandimarte for the strange fascist law "on celibacy". In 1944 he became an opponent to the fascism in the "Resistenza" and was finally killed by the Nazis in La Storta, near Roma, on 4 June 1944. Therefore, the research and development team was substantially composed by the Tiberio-Carrara tandem.

Tiberio's team at RIEC implemented several experimental sets. The first of them, a frequency-modulated continuous wave (FMCW) radar, called E.C.1 (*Elettronica e Comunicazioni 1*), was dedicated to the practical demonstration of the concept and to the measurements of the radar cross section of targets of military interest. It operated at 200 MHz, had a pair of reflector antennas with a parabolic cylindrical section and was used for the practical demonstration of the theory of the radar equation. On the occasion an experience was set up with the apparatus being installed on a terrace of the Institute with a boat as opportunity target (Figure 4).

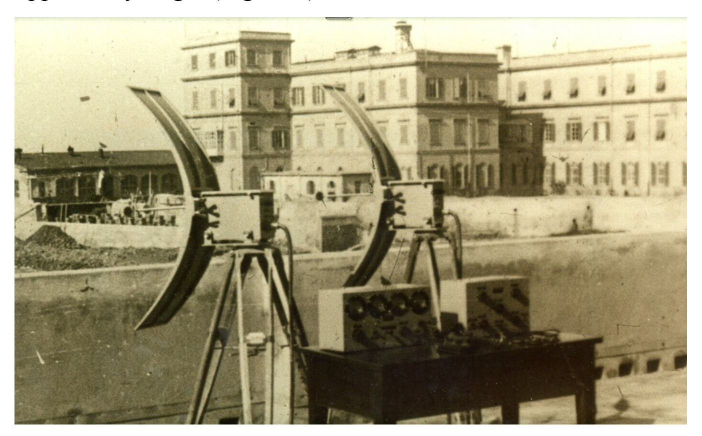


Fig. 4. The FMCW "Radiotelemetro" EC-1 under test on a terrace of the RIEC, 1936.

The first results, although not satisfactory in principle, were useful for an experimental test of the calculation of maximum range. In fact, the first published version of the *"fundamental radar equation"*[2] is due to Ugo Tiberio [20]. As other publications not in English, the paper [20] published on "Alta Frequenza" in May 1939 is summarized in "The Wireless Engineer" of August 1939, in a brief note (no. 3175, reported in [6], p. 457). That note is not a comment, as many – in practice, all – have written, but just an English summary – another example of the "error propagation", said in sect. II.

The limited availability, in Italy, of technologies suited to the high power levels required (order of kW) in the frequency ranges of interest (hundreds of MHz) was one of the main limitations to the development of operationally efficient radars; once the RIEC made the choice of the pulse solution, the problem was exacerbated by the technique of vacuum tubes at that time, developed for the radio communications, i.e. for continuous wave operation. The ensuing version of the RDT named E.C.1-bis, in 1937, did not grant satisfactory results and was promptly abandoned. The very different ensuing prototype named E.C.2., based on the pulsed technique and using the RCA triodes model T 800 on the 1.7 m wavelength, also had serious practical problems. In 1938, the Naval Weapons Directorate, eager to reach in a short time a working prototype, signed a contract with the SAFAR, a company manufacturing Radios, established in Milan in 1923. It was reported that the agreement did not bring to successful results, because of the different views between SAFAR and RIEC, and more specifically, according to somebody, between Ugo Tiberio and the technical director of the company, ing. Arturo Vittorio Castellani (1903-1968). Castellani was a remarkable engineer, developed new of radio equipment and radar: in 1941/1942, within SAFAR, he was the designer of the prototype of the RDT/5 *Veltro*, an Italian *flak* radar with fire control capabilities. During the war he took care of the industrial production of other radar sets (EC3 bis, EC3 ter-*Gufo*).

Given the slowness with which the industry implemented what was designed by the researchers and given the small quantities produced, the Navy had to find other ways to obtain the required peak power. With the international market still open, they could initially purchase from the USA, at the RCA, some powerful enough vacuum tubes. Two prototypes were experimentally tested at the R.I.E.C. from 1939: the coastal apparatus called RDT 3, and the naval one called EC 3, (from December 1940 modified as EC 3-bis). These trials showed some possibility of achieving significant operational results, but only the EC 3 apparatus (a pulse radar, with a double horn antenna, operating on the 70 cm wavelength, developed at the RIEC from the end of 1939, using conventional Philips triodes in transmission and a new, highly sensitive super-reaction receiver) made it possible obtaining significant results. The folowing model EC 3bis (1941) had a super-het receiver and a higher transmission power (1 kW) thanks to the new Philips tubes with a greater cathode efficiency. The first detection (by acoustic receiving) of a target of opportunity (a tug) at approximately 2 km offshore from the Academy of Livorno took place on April 14th, 1941. After a slowdown in 1940 and 1941, the research and development activities on Italian radar

2 In the formulation by Tiberio, who uses the field strength in place of the power density, the square of the distance appears in place of the fourth power. Hence, the equivalent concept of *Forza cimomotrice* (from the Greek *kyma*, wave), which represents, in the wave emitted by a source and measured at a given distance from it, the product of the field intensity by the distance, a product that in free propagation remains unchanged at large distances (i.e. in the so-called far-field). By applying this concept to the backscattered field from a target, Tiberio derived to the radar equation. According to it, the field strength (*V/m*) backscattered from a target at a distance R is given by the product of the "equivalent length of re-radiation" of the target (*m*) by the transmitted *Forza cimomotrice* ($V{\cdot}m$) divided by the square of the distance, R^2 (m^2), a result equivalent to the modern formulation. Tiberio considered, at first instance, a target made up by a metallic wire (for complex targets, Tiberio considered the decomposition into wires).

had a hectic restart in April 1941, immediately after the well known Cape Matapan night naval battle, with the involvement of the industrial apparatus. Summing up, at the date of Cape Matapan two types of prototype were available at RIEC. One of them, designed for the coastal installations, operate at nominal wavelengths about 1.5 m, and was called *RDT 3* (later, *Folaga*), see Figure 5.

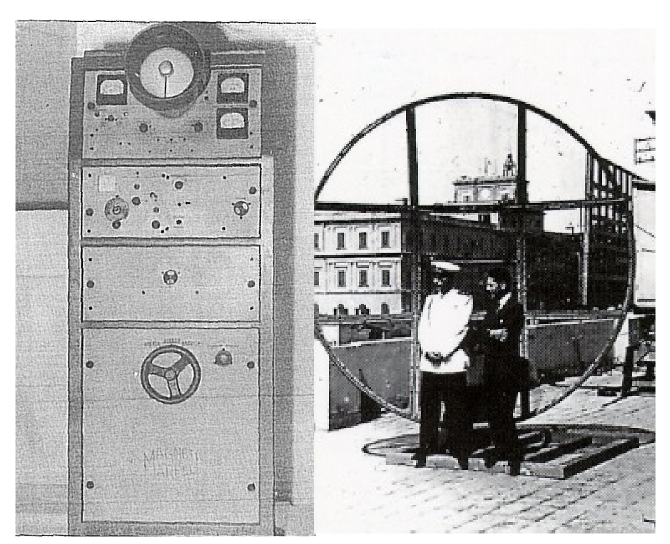


Fig. 5. Video Detector and Antenna of the "Folaga" coastal radar (RIEC, 1943).

It is reminded that the latest version of the *Folaga* during the experimental tests carried out on the terrace of the R.I.E.C. on May, 1943 was able to detect at more than 200 km a mass raid of one hundred American aircraft that were arriving from Sardinia to bomb the city of Livorno.

The other, famous radar developed at RIEC for naval installations was the E.C.3 ter, or *Gufo*. The *Gufo* (Figure 6) had interesting performances thanks to its transmitting system (based on new triodes FIVRE model 1628, due to Nello Carrara) having a peak power as high as 10 kW.

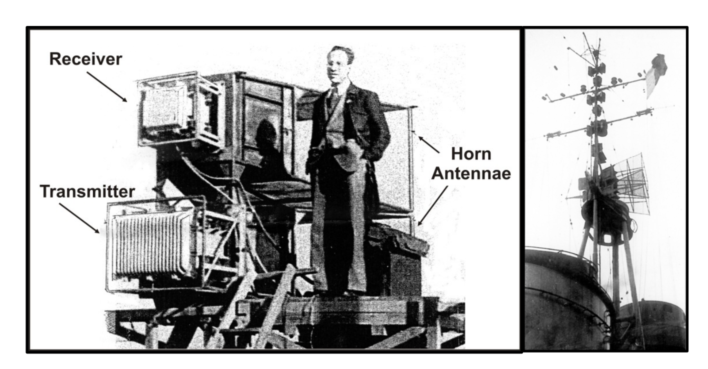


Fig. 6. The E.C. 3/ter *"Gufo"* with Federico Brando from SAFAR and the tripod at the bow of the light cruiser Scipione Africano with the antennae (Tx and Rx) of *"Gufo"*.

With this successful apparatus it was possible to detect air targets at a distance of 120 Km and naval targets at 15 to 30 Km (depending on antenna height over sea).

IV. Conclusion

An attempt has been done to describe early developments of naval Italian radar until September 8th, 1943. Other important contributions in the same time frame, including the work by the group of Air Force (DSSE, Guidonia) headed by Algeri Marino, as well by industries (SAFAR, Marelli, Galileo, …) are not described here for space limitations.

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